

2015 NASA Astrobiology Early Career Collaboration Award Report: **Preservation of Lipid Biomarkers in the Hyperarid Core of the Atacama Desert**

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A Martian Landscape: The Yungay hyperarid core of the Atacama Desert has experienced approximately two million years of extreme dryness. The terrain has been shaped by primary wind erosion leading to the formation of ventifacts and a lack of habitation by plants or active soil microbial communities.

Summary

Lipid biomarkers were analyzed in soils from the hyperarid core of the Atacama Desert to understand biomarker preservation under extreme and prolonged dryness, and very limited biological degradation. Total lipid extracts reveal a remarkable degree of biomarker preservation even in the oldest soils analyzed (ca. 2 Myr) indicating that typical diagenetic processes of lipid destruction are arrested under extreme dryness.

Introduction

Molecular biomarkers are the most direct biosignatures of life on early Earth and a key target in the search for life on Mars. Lipid biomarkers are of particular interest given their ability to survive oxidative degradation and record microbial presence and activity of microorganisms that occurred billions of years ago (*Eigenbrode, 2008*). Environmental conditions that suspend biotic and abiotic degradative processes prior to lithification can lead to enhanced biomolecular preservation over geological time-scales. The hyperarid core of the Atacama Desert in northern Chile offers a unique environment to investigate lipid biomarker taphonomy under extreme and prolonged dryness. We investigated the accumulation and degree of preservation of lipid biomarkers in million-year-old hyperarid soils where primarily abiotic conditions influence their taphonomy.

Abbreviated Methods

Soils were extracted and free and membrane bound lipids were analyzed across a vertical profile of 2.5 meters in the Yungay hyper-arid core of the Atacama Desert. Due to the extremely low inventory of biomass in Atacama soils, samples were collected by scientists wearing cleanroom suits to minimize anthropogenic contamination during sampling (*Figure 1*).



Figure 1: Soil samples being collected by Wilhelm in a clean room suit to minimize introduction of anthropogenic contaminants while sampling in the Atacama Desert (photo credit: A. Davila).

Summons Lab: For each unique sample, approximately 100 g of soil was pulverized with a mortar and pestle. Soils were extracted three times using a modified Bligh Dyer [refs] extraction protocol in which a slurry was created using a monophasic mixture of geo-clean water, methanol, dichloromethane, and soil. This mixture was separated and then resultant lipid fraction was collected and evaporated to near dryness. Medium acid methanolysis and derivatization with Bis-(trimethylsilyl) trifluoroacetamide (BSTFA) was performed on the concentrated lipid fraction for detection of membrane-bound fatty

acids and free fatty acids. Extracts were run on GC-MS and LC-MS. Peak areas were quantified by comparison to an internal standard.

Eigenbrode Lab: Evolved gas analysis (EGA) was performed on approximately 20 mg of pulverized soil for each unique sample. EGA parameters were similar to that of the Sample Analysis at Mars (SAM) instrument aboard the Mars Science Laboratory (hold at 50°C for 10 min, ramp at 35°C/min to 1050°C, hold for 6 min).

Preliminary Results & Discussion

Total Lipid Extracts: Total lipid extracts reveal a remarkable degree of structural preservation in lipids given the age of the soils. Fatty acid methyl esters (FAMES), derived from intact polar membrane lipids as well as from free fatty acids were found have retained their carboxylic acid groups, double bonds, branches, and a large diversity in carbon chain lengths.

A central issue we are trying to address with this analysis is the potential transport and redistribution of lipids in the soil column in the absence of plant-driven carbon cycling with only abiotic processes acting. The total abundance in FAMES was found to increase with depth (*Figure 2*). The similarity in the FAME diversity and abundance above and below a 1.5 m deep halite horizon suggests that lipids may have been buried with very limited or no vertical transport.

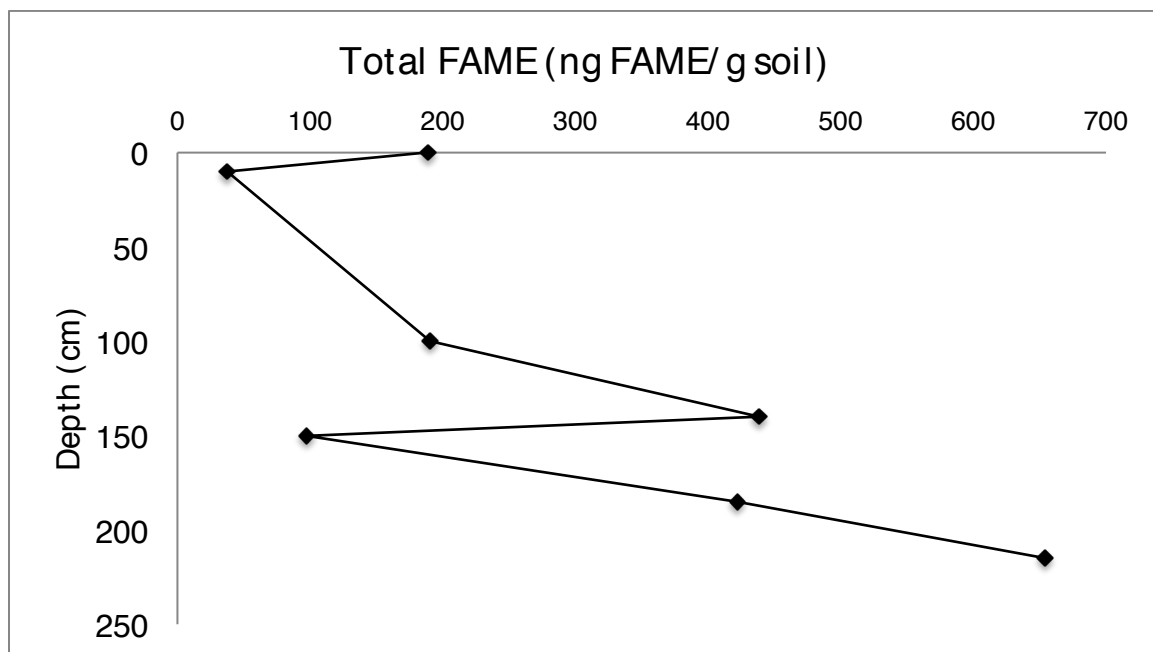


Figure 2: Changes in the abundance of fatty acid methyl esters (FAMES) with depth in the hyperarid core of the Atacama Desert.

Evolved Gas Analysis: Surface soils across the Atacama's precipitation gradient from Yungay to Chañaral have very similar evolved gas analysis (EGA) signals, dominated by H₂O and CO₂. The similarity in the EGA signal is unexpected given the differences in

that habitability of the soils. Chañaral soils harbor active soil communities, lichens, plant material, and hypolithic communities, all of which are absent from Yungay soils. Additionally, O₂ and HCl traces were relatively featureless and two to three orders of magnitude less abundant than H₂O, which is perhaps unexpected given these soils are known to contain perchlorate at the ppm level.

In soil pit samples known to contain more organic material than surface soils (215 cm depth), masses consistent with chlorobenzene fragments (m/z 112 & 114) were present in the EGA signal (*Figure 3*). Pyrolysis of functionalized aromatics in the presence of perchlorates has been demonstrated to form chlorobenzene. The temperatures of the first release of chlorobenzene fragments in soils from 215 cm depth are consistent with what has been observed in SAM EGA data from the Cumberland drill hole in the Sheepbed mudstone at Yellowknife Bay.

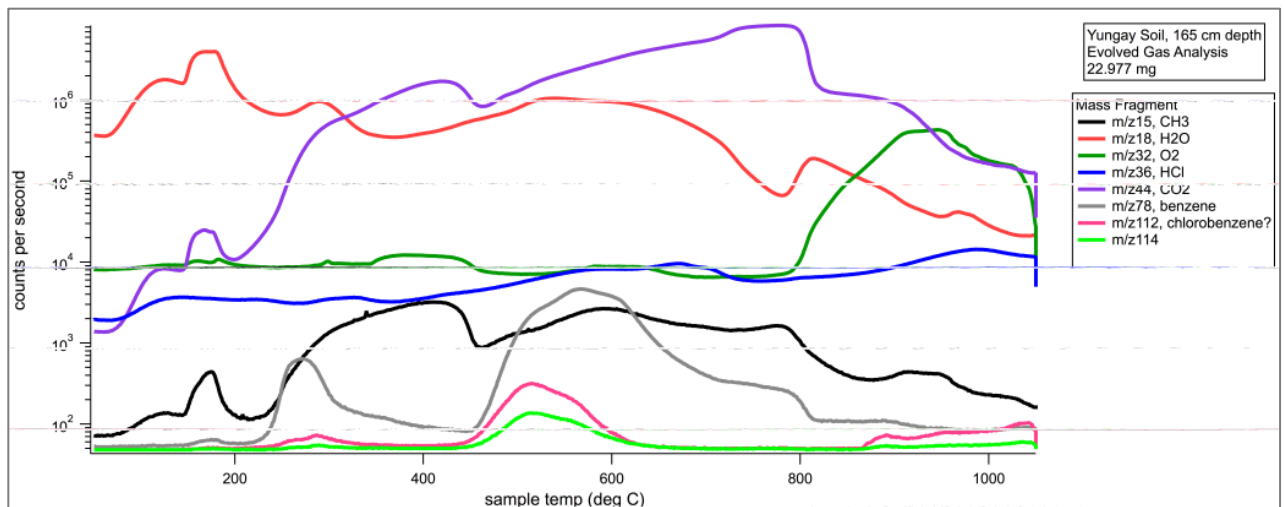


Figure 3: Detection of chlorobenzene in deep clay-rich soils in the Yungay region of the Atacama Desert using SAM-like evolved gas analysis.

Conference Presentations & Expected Publication

Results from this study were presented at the 2015 Astrobiology Science Conference in Chicago, IL, and will be presented at the 2015 American Geophysical Union Meeting in San Francisco, CA. A publication summarizing major results is currently being prepared.

Additional Collaborators & Acknowledgments

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